REMARKS

Applicants respectfully request reconsideration and allowance of all pending claims.

I. Status of Pending Claims

Claims 1-75 remain pending in the present application.

II. Claim Rejections under 35 U.S.C. §103

II.A. Rejection of Claims 1-58 over Sung et al. (U.S. 5,817,176)

Reconsideration is respectfully requested of the rejection of claims 1-58 as being unpatentable over Sung et al. (U.S. 5,817,176).

Among other things, applicants' claim 1 is directed to a process for pulling a single crystal silicon ingot in accordance with the Czochralski method, the process comprising:

> decreasing a mean crucible rotation rate (CR) as a function of increasing axial length of the constant diameter portion of the ingot wherein the mean crucible rotation rate at a position, P_1, is greater than the mean crucible rotation rate at a position, P_2, wherein $D_2 \geq (D_1 + 0.1L)$; and,
>
> controlling an average axial oxygen content in the constant diameter portion to be substantially constant by crucible rotation rate modulation (CRM).

The Sung et al. reference is cited for describing a pulling method in which the rotation rate of the crucible is modulated during ingot growth according to a sine wave function. The Office asserts that the difference between claim 1 and the disclosure of Sung et al. with respect to the formulae used to determine rotation changes, in the absence of unexpected results, "would have been obvious to one of ordinary skill in the art to

determine through routine experimentation the optimum, operable formulae in the Sung et al. reference in order to increase control and quality of the growing ingot." Page 3 of the Office Action mailed June 14, 2005.

Applicants respectfully submit that the Office has not established the prima facie case of obviousness with respect to claim 1 because the cited reference (1) fails to teach or suggest all of the claim 1 limitations and (2) provides no motivation or suggestion to modify the Sung et al. rotation rates to achieve the rotation rates required by claim 1.

II.A.1. The Reference Does Not Teach or Suggest All of the Limitations of Claim 1

In the context of establishing a prima facie case of obviousness,

> Finally, the prior art reference (or references when combined) must teach or suggest all the claim limitations. MPEP 2143.

Claim 1 is directed to a pulling process comprising the combination of (1) decreasing a mean crucible rotation rate (CR) as a function of increasing axial length of the constant diameter portion of the ingot...and (2) controlling an average axial oxygen content in the constant diameter portion to be substantially constant by crucible rotation rate modulation (CRM). Sung et al. fail to teach either of these steps.

While Sung et al. teach a method for modulating the rotation rate of the crucible during an ingot pulling process, Sung et al. do not teach that the mean crucible rotation rate decreases as a function of increasing axial length of the constant diameter portion of the ingot. The crucible rotation modulation rate of Sung et al. is depicted by the formula in Col. 3, line 30-42:

$$\text{(1)} \quad \Omega = \Omega_o(1 + A\sin 2\pi ft)$$

The formula can be rewritten as follows:

$$(2) \quad \Omega = \Omega_o + \Omega_o A \sin 2\pi f t$$

Accordingly, the crucible rotation rate is a function of a constant factor, Ω_o, and a variable factor, $\Omega_o A\sin 2\pi ft$. The constant factor, Ω_o, is defined as the crucible rotation rate in a conventional ingot pulling process. The value of variable factor $\Omega_o A\sin 2\pi ft$ varies as a function of frequency, f, and time, t, during each period defined by ft between a minimum value of $-\Omega_o A$ and a maximum value of $+\Omega_o A$. Each and every instantaneous value of the variable factor during a period has a corresponding instantaneous value of equal and opposite magnitude. Accordingly, the sum, and necessarily the mean, of all instantaneous values of the variable factor during each period must equal 0. The mean crucible rotation rate, Ω, therefore must equal the crucible rotation rate in a conventional ingot pulling process, Ω_o, throughout each period of the pulling process. Because there is no factor present in the formula of Sung et al. to decrease the value of the constant factor, Ω_o, as a function of increasing axial length of the constant diameter portion of the ingot, it necessarily follows that the mean crucible rotation rate, Ω, stays constant during the pulling process. Therefore, Sung et al. do not teach or suggest the claim 1 limitation of decreasing the mean value as a function of increasing axial length of the constant diameter portion of the ingot.

Moreover, Sung et al. do not teach controlling an average axial oxygen content in the constant diameter portion to be substantially constant by crucible rotation rate modulation (CRM). While Sung et al. teach crucible rotation rate modulation governed by the sine wave function to dampen temperature oscillation (See FIGS. 4-7), Sung et al. do not teach the claim 1 limitation of controlling the average axial oxygen content in the constant diameter portion by CRM.

Since Sung et al. neither teach nor suggest (1) decreasing a mean crucible rotation rate (CR) as a function of increasing

axial length of the constant diameter portion of the ingot or (2) controlling average axial oxygen content in the constant diameter portion either singly or in combination, it necessarily follows that the Sung et al. reference does not render claim 1 obvious.

II.A.2. There is no suggestion or motivation to modify the reference teachings to achieve the invention defined by claim 1.

In the context of establishing a prima facie case of obviousness,

> First, there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. MPEP 2143.

The Sung et al. reference provides no motivation to the ordinary artisan to modify its teachings to achieve the process defined by applicants' claim 1.

Sung et al. would not have motivated the ordinary artisan to decrease the mean crucible rotation rate as a function of axial length. As described in applicants' specification, decreasing the mean crucible rotation rate provides certain advantages:

> [0027] Generally speaking, in accordance with the present invention, it has been discovered that the mean crucible rotation rate (CR) may be controlled to alter the shape of the melt-solid interface and the average axial temperature gradient in the crystal, G_0, defined over the temperature range from solidification to a temperature of greater than about 1300°C (e.g., 1325°C, 1350°C or more), as illustrated by Figs. 2 and 3, respectively. In particular, **the process of the present invention utilizes CR to increase the average axial temperature gradient near a central axis of the growing crystal while having substantially no effect on the gradient near a lateral surface thereof**, even at values of G_0 which are substantially higher than conventional processes, **and, as a result, effectively renders v/G_0 more uniform as a function of radius.**

> [0029] **It is well-recognized that increasing G_0 is desirable because this in turn allows v,** primarily controlled by the pull rate, **to be increased while still obtaining the same v/G_0 ratio, thus increasing throughput of the same type and quality of single crystal silicon.** The present approach for controlling or altering G_0, particularly at or near the central axis, is distinguishable from other approaches to increase G_0 which utilize hot zone design. In particular, such conventional approaches generally result in an increase is G_0 over substantially the entire radius of the ingot, particularly at the radial edge, while the present process achieves a higher G_0 near the central axis and little if any change in G_0 at the radial edge. (Applicants' specification at paragraphs 0027 and 0029, emphasis added.)

Sung et al. do not disclose these advantages. On the topic of mean crucible rotation rate, Sung et al. merely disclose that the rotation rate may be modulated to reduce temperature oscillations and thus to reduce striations in the crystal. See Col. 4, line 65 to Col. 5, line 6 of Sung et al. The reference does not disclose anything with respect to the advantages of altering the shape of the melt/solid interface and flattening the average axial temperature gradient from center to edge, thus allowing an increase in pull velocity and throughput. If anything, therefore, Sung et al. would not provide a person of ordinary skill with a basis to appreciate the advantages that could be derived by decreasing the mean crucible rotation rate and would not have motivated the ordinary artisan to modify the process of Sung et al. to achieve the process defined by applicants' claim 1, including the decreased mean crucible rotation rate as a function of axial length.

Additionally, Sung et al. would not have motivated the ordinary artisan to use CRM to control the average axial oxygen content in the constant diameter portion. Sung et al. provide no description of controlling the oxygen content of its ingots. Since Sung et al. attach no apparent significance to the oxygen

content of the ingots of Sung et al., it necessarily follows that the reference would not have motivated the ordinary artisan to modify the process of Sung et al. to achieve the process defined by applicants' claim 1, including controlling the average axial oxygen content by CRM.

Since Sung et al. attach no significance to the oxygen content of its ingots and provides no motivation to decrease the mean crucible rotation rate, it necessarily follows that their disclosure would not have motivated a person of ordinary skill to modify the process of Sung et al. to achieve the process defined by applicants' claim 1.

II.A.3. Applicants do not have to show "unexpected results."

The prima facie case having not been made, the applicants submit that the language "absence of unexpected results" on page 3 of the Office Action date 6/14/2005 is inapposite. Specifically, the burden is not on the applicant to show unexpected results unless the Office has established a prima facie case. MPEP 2144.09. Applicants submit that, for the reasons stated in this Response, the Office has failed to establish its prima facie case.

Regardless, applicants can show advantageous results derived from their process not disclosed by Sung et al. For example, decreasing the mean crucible rotation rate can be used to control, and thereby increase, the axial temperature gradient, G_o, at the ingot center while having substantially no effect on the gradient near the lateral surface. Control of this factor, along with other factors such as pull rate, ensures that each ingot segment is uniformly grown and can limit, and even prevent, the formation of agglomerated intrinsic point defects in a segment or all of the constant diameter portion of the ingot. See applicants' specification at paragraphs 0027 and 0031. This

advantageous result can be achieved in combination with using CRM to render the average axial oxygen content substantially uniform. See applicants' specification at paragraphs 0050 and 0051.

II.A.4. Claims 2-42 are patentable.

Claims 2-42 depend from claim 1 and are patentable for the same reasons as claim 1 and by virtue of the additional requirements therein.

For example, claims 2-27 further limit the variables D, DD, P and PP, which are variables relating to the position and distance where transitions in mean crucible rotation rate and CRM occur, i.e., where the mean crucible rotation rate is decreased or the amplitude of CRM modulation is increased. The Sung et al. reference provides no teaching of or motivation toward these position and limitation variables. In the formula defined by Sung et al. at Col. 3, lines 30-42, the variables Ω, which defines crucible rotation rate as a function of frequency and time, and Ω_o, which define the mean crucible rotation rate, contain no factors which would indicate transitioning from higher mean crucible rotation rates to lower mean crucible rotation rates at any position or distance along the constant diameter portion of the ingot. Further in that formula, the variable A, which defines the amplitude, contains no factors which would indicate transitioning from a lower absolute value for amplitude to higher absolute value for amplitude at any position or distance along the constant diameter portion of the ingot.

Claims 28-32 further limit CRM by defining the amplitude during CRM. The Sung et al. reference does not teach or motivate toward these claims because Sung et al. teach constant amplitude during CRM and provide no motivation toward changing the amplitude as a function of the length of the constant diameter portion.

Claims 36-37 limit the average axial oxygen content to

certain variance. The Sung et al. reference does not teach or motivate toward these claims because the reference does not teach controlling the average axial oxygen content.

II.A.5. Claims 43-58 are patentable.

Claim 43 is directed toward a process for pulling a single crystal silicon ingot comprising:

> rotating a crucible at a mean crucible rotation rate (CR) during growth of the constant diameter portion which is sufficient to obtain a melt-solid interface having a height near the axis, Z_a, of at least about 5 mm, as measured from the melt surface, and a height $Z_{R/2}$, where $Z_{R/2}$ is the height of the interface above the melt surface at about a midpoint of the radius, which is at least about 120% of Z_a; and,
>
> controlling an average axial oxygen content in the constant diameter portion to be substantially constant by crucible rotation modulation (CRM).

Claim 43 is patentable because the Sung et al. reference does not teach or suggest the height of the melt-solid interface near the axis. Additionally, claim 43 is patentable for the reasons explained above in connection with claim 1, specifically the Sung et al. reference does not teach controlling an average axial oxygen content by CRM.

Claims 44-58 depend from claim 43 and are patentable for the same reasons as claim 43 and by virtue of the additional requirements therein.

II.B. Rejection of Claims 59-75 over Sung et al. (U.S. 5,817,176)

Claim 59 is directed to a process for pulling a single crystal silicon ingot, the process comprising:

> ...controlling a ratio v/G_0, wherein v is a growth velocity and G_0 is an average axial temperature gradient over a temperature range from solidification to no less than about 1300°C for at least a segment of the constant diameter portion of the ingot, control of

said ratio comprising decreasing a mean crucible rotation rate (CR) as said segment is grown;

controlling an average axial oxygen content in the segment to be substantially constant by crucible rotation modulation (CRM)...

Claim 59 is patentable for the reasons explained above in connection with claim 1. Specifically, Sung et al. do not teach either decreasing a mean crucible rate as a segment of the ingot is grown or controlling an average axial oxygen content in the segment to be substantially constant by (CRM).

Claims 60-75 depend from claim 59 and are patentable for the same reasons as claim 59 and by virtue of the additional requirements therein.

CONCLUSION

In view of the foregoing, favorable reconsideration and allowance of all pending claims is respectfully requested.

Applicants do not believe that a fee is due in connection with this response. If, however, the Commissioner determines that a fee is due, he is authorized to charge Deposit Account No. 19-1345.

Respectfully submitted,

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